Q6.5 The speed changes. The tangential force component causes tangential acceleration.

Q6.9 I would not accept that statement for two reasons. First, to be "beyond the pull of gravity," one would have to be infinitely far away from all other matter. Second, astronauts in orbit are moving in a circular path. It is the gravitational pull of Earth on the astronauts that keeps them in orbit. In the space shuttle, just above the atmosphere, gravity is only slightly weaker than at the Earth's surface. Gravity does its job on an orbiting spacecraft, because the craft feels no other forces and is in free fall.

P6.5 (a) $\boxed{\text{static friction}}$

(b) $m a\hat{\mathbf{i}} = f\hat{\mathbf{i}} + n\hat{\mathbf{j}} + mg\left(-\hat{\mathbf{j}}\right)$

$\sum F_y = 0 = n - mg$

thus $n = mg$ and $\sum F_r = m\dfrac{v^2}{r} = f = \mu n = \mu mg$.

Then $\mu = \dfrac{v^2}{rg} = \dfrac{\left(50.0\text{ cm/s}\right)^2}{\left(30.0\text{ cm}\right)\left(980\text{ cm/s}^2\right)} = \boxed{0.0850}$.

P6.15 Let the tension at the lowest point be T.

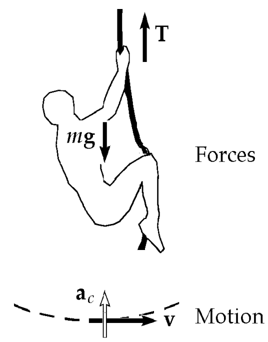


FIG. P6.15

$$\sum F = ma:\quad T - mg = ma_c = \frac{mv^2}{r}$$

$$T = m\left(g + \frac{v^2}{r}\right)$$

$$T = \left(85.0\text{ kg}\right)\left[9.80\text{ m/s}^2 + \frac{\left(8.00\text{ m/s}\right)^2}{10.0\text{ m}}\right] = 1.38\text{ kN} > 1\,000\text{ N}$$

$\boxed{\text{He doesn't make it across the river because the vine breaks.}}$

P6.52 (a) $\sum F_y = ma_y = \dfrac{mv^2}{R}$ $\qquad mg - n = \dfrac{mv^2}{R}$ $\qquad n = \boxed{mg - \dfrac{mv^2}{R}}$

(b) When $n = 0$, $\qquad mg = \dfrac{mv^2}{R}$

Then, $\qquad v = \boxed{\sqrt{gR}}$.

P6.58 (a) Since the object of mass m_2 is in equilibrium, $\qquad \sum F_y = T - m_2 g = 0$ or $\qquad T = \boxed{m_2 g}$.

(b) The tension in the string provides the required centripetal acceleration of the puck.

Thus, $\qquad F_c = T = \boxed{m_2 g}$.

(c) From $\qquad F_c = \dfrac{m_1 v^2}{R}$ we have $\qquad v = \sqrt{\dfrac{RF_c}{m_1}} = \boxed{\sqrt{\left(\dfrac{m_2}{m_1}\right)gR}}$.

P6.2 215 N horizontally inward

P6.4 6.22×10^{-12} N

P6.6 (a) 1.65 km/s; (b) 6.84×10^{3} s

P6.8 0.966 g

P6.10 (a) $\left(-0.233\,\hat{\mathbf{i}} + 0.163\,\hat{\mathbf{j}}\right)\text{m/s}^2$; (b) 6.53 m/s; (c) $\left(-0.181\,\hat{\mathbf{i}} + 0.181\,\hat{\mathbf{j}}\right)\text{m/s}^2$

P6.12 2.06×10^{3} rev/min

P6.14 (a) $\sqrt{R\left(\dfrac{2T}{m} - g\right)}$; (b) $2T$ upward

P6.16 (a) 1.33 m/s^2; (b) 1.79 m/s^2 forward and 48.0° inward

P6.18 8.88 N

P6.20 (a) 8.62 m; (b) Mg downward; (c) 8.45 m/s^2, Unless they are belted in, the riders will fall from the cars.

P6.22 $15.3\ \mathrm{m/s}$ Straight across the dashboard to the left

P6.24 0.527°

P6.26 (a) 1.41 h; (b) 17.1

P6.28 $\mu_k = \dfrac{2(vt-L)}{(g+a)t^2}$

P6.30 (a) $2.38\times10^5\ \mathrm{m/s^2}$ horizontally inward $= 2.43\times10^4 g$; (b) 360 N inward perp to cone; (c) $47.5\times10^4\ \mathrm{m/s^2}$

P6.32 (a) $6.27\ \mathrm{m/s^2}$ downward; (b) 784 N up; (c) 283 N up

P6.34 (a) $53.8\ \mathrm{m/s}$; (b) 148 m

P6.36 1.40

P6.38 $-0.212\ \mathrm{m/s^2}$

P6.42 $36.5\ \mathrm{m/s}$

P6.44 (a) $0.980\ \mathrm{m/s}$; (b) see the solution

P6.46 (a) $7.70\times10^{-4}\ \mathrm{kg/m}$; (b) 0.998 N; (c) The ball reaches max height 49 m. Its flight lasts 6.3 s. Impact speed $27\ \mathrm{m/s}$.

P6.48 (a) see the solution; (b) 81.8 m; (c) 15.9°

P6.50 $0.835\ \mathrm{rev/s}$

P6.52 (a) $mg - \dfrac{mv^2}{R}$; (b) $v=\sqrt{gR}$

P6.54 (a) $2.63\ \mathrm{m/s^2}$; (b) 201 m; (c) $17.7\ \mathrm{m/s}$

P6.56 (a) 106 N; (b) 0.396

P6.58 (a) $m_2 g$; (b) $m_2 g$; (c) $\sqrt{\left(\dfrac{m_2}{m_1}\right) gR}$

P6.60 $62.2\ \mathrm{rev/min}$

P6.62 $2.14\ \mathrm{rev/min}$

P6.64 (a) $v=\sqrt{\pi R g}$; (b) $m\pi g$

P6.66 (a) 8.04 s; (b) $379\ \mathrm{m/s}$; (c) $1.19\ \mathrm{cm/s}$; (d) 9.55 cm

P6.68 (a) either 70.4° or 0°; (b) 0°

P6.70 (a) $78.3\ \mathrm{m/s}$; (b) 11.1 s; (c) 121 m

Q7.6 No. The vectors might be in the third and fourth quadrants, but if the angle between them is less than 90° their dot product is positive.

Q7.19 The rock increases in speed. The farther it has fallen, the more force it might exert on the sand at the bottom; but it might instead make a deeper crater with an equal-size average force. The farther it falls, the more work it will do in stopping. Its kinetic energy is increasing due to the work that the gravitational force does on it.

P7.7 (a) $W = \mathbf{F}\cdot\Delta\mathbf{r} = F_x x + F_y y = (6.00)(3.00)\ \mathrm{N\cdot m} + (-2.00)(1.00)\ \mathrm{N\cdot m} = \boxed{16.0\ \mathrm{J}}$

(b) $\theta = \cos^{-1}\left(\dfrac{\mathbf{F}\cdot\Delta\mathbf{r}}{F\Delta r}\right) = \cos^{-1}\dfrac{16}{\sqrt{\left((6.00)^2+(-2.00)^2\right)\left((3.00)^2+(1.00)^2\right)}} = \boxed{36.9^\circ}$

***P7.21** The same force makes both light springs stretch.

(a) The hanging mass moves down by

$$x = x_1 + x_2 = \frac{mg}{k_1} + \frac{mg}{k_2} = mg\left(\frac{1}{k_1}+\frac{1}{k_2}\right)$$

$$= 1.5\ \mathrm{kg}\ 9.8\ \mathrm{m/s^2}\left(\frac{1\ \mathrm{m}}{1\,200\ \mathrm{N}} + \frac{1\ \mathrm{m}}{1\,800\ \mathrm{N}}\right) = \boxed{2.04\times10^{-2}\ \mathrm{m}}$$

(b) We define the effective spring constant as

$$k = \frac{F}{x} = \frac{mg}{mg\left(1/k_1 + 1/k_2\right)} = \left(\frac{1}{k_1} + \frac{1}{k_2}\right)^{-1}$$

$$= \left(\frac{1\text{ m}}{1\,200\text{ N}} + \frac{1\text{ m}}{1\,800\text{ N}}\right)^{-1} = \boxed{720\text{ N/m}}$$

***P7.22** See the solution to problem 7.21.

(a) $x = mg\left(\frac{1}{k_1} + \frac{1}{k_2}\right)$ (b) $k = \left(\frac{1}{k_1} + \frac{1}{k_2}\right)^{-1}$

P7.32 (a) $W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2 = \frac{1}{2}(500)\left(5.00\times 10^{-2}\right)^2 - 0 = 0.625\text{ J}$

$W_s = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 - 0$

so $v_f = \sqrt{\frac{2\left(\sum W\right)}{m}} = \sqrt{\frac{2(0.625)}{2.00}}\text{ m/s} = \boxed{0.791\text{ m/s}}$

(b) $\frac{1}{2}mv_i^2 - f_k\Delta x + W_s = \frac{1}{2}mv_f^2$

$0 - (0.350)(2.00)(9.80)(0.050\,0)\text{ J} + 0.625\text{ J} = \frac{1}{2}mv_f^2$

$0.282\text{ J} = \frac{1}{2}(2.00\text{ kg})v_f^2$

$v_f = \sqrt{\frac{2(0.282)}{2.00}}\text{ m/s} = \boxed{0.531\text{ m/s}}$

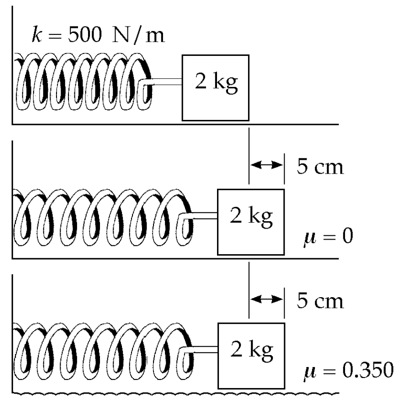


FIG. P7.32

P7.48 (a) $\mathbf{A}\cdot\hat{\mathbf{i}} = (A)(1)\cos\alpha$. But also, $\mathbf{A}\cdot\hat{\mathbf{i}} = A_x$.

Thus, $(A)(1)\cos\alpha = A_x$ or $\boxed{\cos\alpha = \frac{A_x}{A}}$. Similarly, $\boxed{\cos\beta = \frac{A_y}{A}}$

and $\boxed{\cos\gamma = \frac{A_z}{A}}$ where $A = \sqrt{A_x^2 + A_y^2 + A_z^2}$.

(b) $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = \left(\frac{A_x}{A}\right)^2 + \left(\frac{A_y}{A}\right)^2 + \left(\frac{A_z}{A}\right)^2 = \frac{A^2}{A^2} = 1$

P7.63 $K_i + W_s + W_g = K_f$

$\frac{1}{2}mv_i^2 + \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2 + mg\Delta x\cos\theta = \frac{1}{2}mv_f^2$

$0 + \frac{1}{2}kx_i^2 - 0 + mgx_i\cos 100° = \frac{1}{2}mv_f^2$

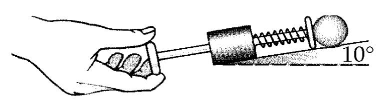


FIG. P7.63

$\frac{1}{2}(1.20\text{ N/cm})(5.00\text{ cm})(0.050\,0\text{ m}) - (0.100\text{ kg})(9.80\text{ m/s}^2)(0.050\,0\text{ m})\sin 10.0° = \frac{1}{2}(0.100\text{ kg})v^2$

$0.150\text{ J} - 8.51\times 10^{-3}\text{ J} = (0.050\,0\text{ kg})v^2$

$v = \sqrt{\frac{0.141}{0.050\,0}} = \boxed{1.68\text{ m/s}}$

P7.2 $1.59\times 10^3\text{ J}$

P7.4 (a) $3.28\times 10^{-2}\text{ J}$; (b) $-3.28\times 10^{-2}\text{ J}$

P7.8 5.33 W

P7.10 16.0

P7.12 (a) see the solution; (b) -12.0 J

P7.14 50.0 J

P7.16 (a) 575 N/m; (b) 46.0 J

P7.18 (a) 9.00 kJ; (b) 11.7 kJ, larger by 29.6%

P7.20 (a) see the solution; (b) mgR

P7.22 (a) $\frac{mg}{k_1}+\frac{mg}{k_2}$; (b) $\left(\frac{1}{k_1}+\frac{1}{k_2}\right)^{-1}$

P7.24 (a) 1.20 J; (b) 5.00 m/s; (c) 6.30 J

P7.26 (a) 60.0 J; (b) 60.0 J

P7.28 (a) 1.94 m/s; (b) 3.35 m/s; (c) 3.87 m/s

P7.30 (a) 3.78×10^{-16} J; (b) $1.35\times10^{-14}\text{ N}$; (c) $1.48\times10^{+16}\text{ m/s}^2$; (d) 1.94 ns

P7.32 (a) 0.791 m/s; (b) 0.531 m/s

P7.34 (a) 329 J; (b) 0; (c) 0; (d) 185 J; (e) 144 J

P7.36 8.01 W

P7.38 $\sim10^4\text{ W}$

P7.40 (a) 5.91 kW; (b) 11.1 kW

P7.42 No. (a) 582; (b) $90.5\text{ W}=0.121\text{ hp}$

Q8.1 The final speed of the children will not depend on the slide length or the presence of bumps if there is no friction. If there is friction, a longer slide will result in a lower final speed. Bumps will have the same effect as they effectively lengthen the distance over which friction can do work, to decrease the total mechanical energy of the children.

Q8.15 Kinetic energy is greatest at the starting point. Gravitational energy is a maximum at the top of the flight of the ball.

P8.5 $U_i+K_i=U_f+K_f$: $\quad mgh+0=mg(2R)+\frac{1}{2}mv^2$

$$g(3.50R)=2g(R)+\frac{1}{2}v^2$$

$$\boxed{v=\sqrt{3.00gR}}$$

$\sum F=m\frac{v^2}{R}$: $\quad n+mg=m\frac{v^2}{R}$

$$n=m\left[\frac{v^2}{R}-g\right]=m\left[\frac{3.00gR}{R}-g\right]=2.00mg$$

$$n=2.00\left(5.00\times10^{-3}\text{ kg}\right)\left(9.80\text{ m/s}^2\right)$$

$$=\boxed{0.0980\text{ N downward}}$$

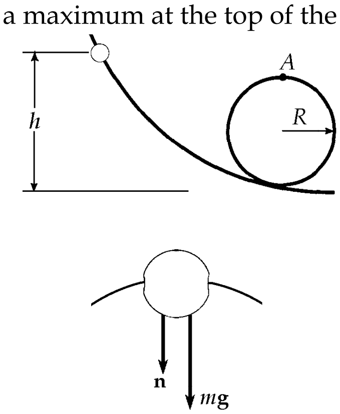


FIG. P8.5

***P8.16** efficiency $=\frac{\text{useful output energy}}{\text{total input energy}}=\frac{\text{useful output power}}{\text{total input power}}$

$$e=\frac{m_{\text{water}}gy/t}{(1/2)m_{\text{air}}\left(v^2/t\right)}=\frac{2\rho_{\text{water}}\left(V_{\text{water}}/t\right)gy}{\rho_{\text{air}}\pi r^2\left(\ell v^2/t\right)}=\frac{2\rho_w\left(V_w/t\right)gy}{\rho_a\pi r^2v^3}$$

where ℓ is the length of a cylinder of air passing through the mill and V_w is the volume of water pumped in time t. We need inject negligible kinetic energy into the water because it starts and ends at rest.

$$\frac{V_w}{t}=\frac{e\rho_a\pi r^2v^3}{2\rho_w gy}=\frac{0.275\left(1.20\text{ kg/m}^3\right)\pi(1.15\text{ m})^2(11\text{ m/s})^3}{2\left(1000\text{ kg/m}^3\right)\left(9.80\text{ m/s}^2\right)35\text{ m}}$$

$$=2.66\times10^{-3}\text{ m}^3/\text{s}\left(\frac{1000\text{ L}}{1\text{ m}^3}\right)\left(\frac{60\text{ s}}{1\text{ min}}\right)=\boxed{160\text{ L/min}}$$

P8.31 $U_i+K_i+\Delta E_{\text{mech}}=U_f+K_f$: $\quad m_2gh-fh=\frac{1}{2}m_1v^2+\frac{1}{2}m_2v^2$

$$f=\mu n=\mu m_1g$$

$$m_2gh-\mu m_1gh=\frac{1}{2}(m_1+m_2)v^2$$

$$v^2=\frac{2(m_2-\mu m_1)(hg)}{m_1+m_2}$$

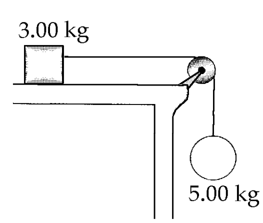


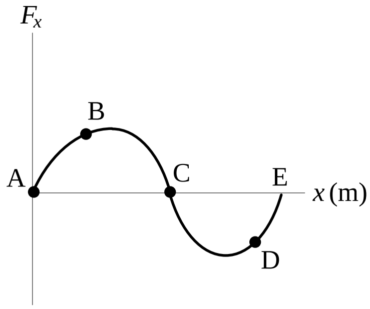
FIG. P8.31

$$v = \sqrt{\frac{2\left(9.80\text{ m/s}^2\right)(1.50\text{ m})\left[5.00\text{ kg} - 0.400(3.00\text{ kg})\right]}{8.00\text{ kg}}} = \boxed{3.74\text{ m/s}}$$

P8.45 (a) F_x is zero at points A, C and E; F_x is positive at point B and negative at point D.

(b) A and E are unstable, and C is stable.

(c)



P8.48 The potential energy of the block-Earth system is mgh.

An amount of energy $\mu_k mgd\cos\theta$ is converted into internal energy due to friction on the incline.

Therefore the final height y_{max} is found from

$$mgy_{max} = mgh - \mu_k mgd\cos\theta$$

where

$$d = \frac{y_{max}}{\sin\theta}$$

$$\therefore mgy_{max} = mgh - \mu_k mgy_{max}\cot\theta$$

Solving,

$$y_{max} = \frac{h}{1 + \mu_k\cot\theta}.$$

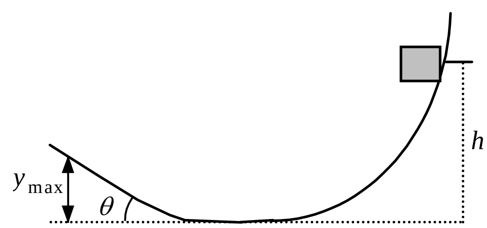
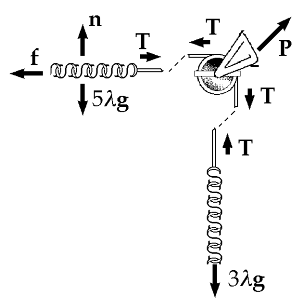


FIG. P8.48

P8.62 Let λ represent the mass of each one meter of the chain and T represent the tension in the chain at the table edge. We imagine the edge to act like a frictionless and massless pulley.



(a) For the five meters on the table with motion impending,

$\sum F_y = 0: \quad +n - 5\lambda g = 0 \qquad n = 5\lambda g$

$f_s \le \mu_s n = 0.6(5\lambda g) = 3\lambda g$

$\sum F_x = 0: \quad +T - f_s = 0 \qquad T = f_s$

$T \le 3\lambda g$

The maximum value is barely enough to support the hanging segment according to

$\sum F_y = 0: \quad +T - 3\lambda g = 0 \qquad T = 3\lambda g$

so it is at this point that the chain starts to slide.

(b) Let x represent the variable distance the chain has slipped since the start.

Then length $(5 - x)$ remains on the table, with now

$\sum F_y = 0: \quad +n - (5 - x)\lambda g = 0 \qquad n = (5 - x)\lambda g$

$f_k = \mu_k n = 0.4(5 - x)\lambda g = 2\lambda g - 0.4x\lambda g$

Consider energies of the chain-Earth system at the initial moment when the chain starts to slip, and a final moment when $x = 5$, when the last link goes over the brink. Measure heights above the final position of the leading end of the chain. At the moment the final link slips off, the center of the chain is at $y_f = 4$ meters.

Originally, 5 meters of chain is at height 8 m and the middle of the dangling segment is at height $8 - \frac{3}{2} = 6.5\text{ m}$.

$$K_i + U_i + \Delta E_{mech} = K_f + U_f: \qquad 0 + \left(m_1 gy_1 + m_2 gy_2\right)_i - \int_i^f f_k dx = \left(\frac{1}{2}mv^2 + mgy\right)_f$$

$$(5\lambda g)8+(3\lambda g)6.5-\int_0^5(2\lambda g-0.4x\lambda g)\,dx=\frac{1}{2}(8\lambda)v^2+(8\lambda g)4$$

$$40.0g+19.5g-2.00g\int_0^5 dx+0.400g\int_0^5 x\,dx=4.00v^2+32.0g$$

$$27.5g-2.00gx\Big|_0^5+0.400g\frac{x^2}{2}\Big|_0^5=4.00v^2$$

$$27.5g-2.00g(5.00)+0.400g(12.5)=4.00v^2$$

$$22.5g=4.00v^2$$

$$v=\sqrt{\frac{(22.5\text{ m})(9.80\text{ m/s}^2)}{4.00}}=\boxed{7.42\text{ m/s}}$$

P8.2 (a) 800 J; (b) 107 J; (c) 0

P8.4 (a) 1.11×10^9 J; (b) 0.2

P8.6 1.84 m

P8.8 (a) 10.2 kW; (b) 10.6 kW; (c) 5.82×10^6 J

P8.10 $d=\dfrac{kx^2}{2mg\sin\theta}-x$

P8.12 (a) see the solution; (b) 60.0°

P8.14 (a) $\sqrt{\dfrac{2(m_1-m_2)gh}{(m_1+m_2)}}$; (b) $\dfrac{2m_1h}{m_1+m_2}$

P8.16 160 L/min

P8.18 40.8°

P8.20 $\left(\dfrac{8gh}{15}\right)^{1/2}$

P8.22 (a) see the solution; (b) 35.0 J

P8.24 (a) $v_B=5.94$ m/s; $v_C=7.67$ m/s; (b) 147 J

P8.26 (a) $U_f=22.0$ J; $E=40.0$ J; (b) Yes. The total mechanical energy changes.

P8.28 194 m

P8.30 2.06 kN up

P8.32 168 J

P8.34 (a) 24.5 m/s; (b) yes; (c) 206 m; (d) Air drag depends strongly on speed.

P8.36 3.92 kJ

P8.38 44.1 kW

P8.40 (a) $\dfrac{Ax^2}{2}-\dfrac{Bx^3}{3}$; (b) $\Delta U=\dfrac{5A}{2}-\dfrac{19B}{3}$; $\Delta K=\dfrac{19B}{3}-\dfrac{5A}{2}$

P8.42 $(7-9x^2y)\hat{\mathbf{i}}-3x^3\hat{\mathbf{j}}$

P8.46 (a) $r=1.5$ mm and 3.2 mm, stable; 2.3 mm and unstable; $r\to\infty$ neutral;
(b) $-5.6\text{ J}\le E<1\text{ J}$; (c) $0.6\text{ mm}\le r\le 3.6\text{ mm}$; (d) 2.6 J; (e) 1.5 mm; (f) 4 J

P8.50 33.4 kW

P8.52 (a) 0.588 J; (b) 0.588 J; (c) 2.42 m/s; (d) 0.196 J; 0.392 J

P8.54 0.115

P8.56 (a) 100 J; (b) 0.410 m; (c) 2.84 m/s; (d) -9.80 mm; (e) 2.85 m/s

P8.58 (a) $(3x^2-4x-3)\hat{\mathbf{i}}$; (b) 1.87; --0.535;

P8.60 (a) 0.378 m; (b) 2.30 m/s; (c) 1.08 m

P8.62 (a) see the solution; (b) 7.42 m/s

P8.64 (a) see the solution; (b) 1.35 m/s; (c) 0.958 m/s; (d) see the solution

P8.66 0.923 m/s

P8.68 $2m$

P8.70 100.6°

P8.74 (a) $14.1\ \text{m/s}$; (b) $-7.90\ \text{J}$; (c) 800 N; (d) 771 N; (e) 1.57 kN up

Q9.10 Momentum conservation is not violated if we choose as our system the planet along with you. When you receive an impulse forward, the Earth receives the same size impulse backwards. The resulting acceleration of the Earth due to this impulse is significantly smaller than your acceleration forward, but the planet's backward momentum is equal in magnitude to your forward momentum.

Q9.21 The planet is in motion around the sun, and thus has momentum and kinetic energy of its own. The spacecraft is directed to cross the planet's orbit behind it, so that the planet's gravity has a component pulling forward on the spacecraft. Since this is an elastic collision, and the velocity of the planet remains nearly unchanged, the probe must both increase speed and change direction for both momentum and kinetic energy to be conserved.

P9.9

$$\Delta \mathbf{p} = \mathbf{F}\Delta t$$

$$\Delta p_y = m\left(v_{fy} - v_{iy}\right) = m\left(v\cos 60.0°\right) - mv\cos 60.0° = 0$$

$$\Delta p_x = m\left(-v\sin 60.0° - v\sin 60.0°\right) = -2mv\sin 60.0°$$

$$= -2(3.00\ \text{kg})(10.0\ \text{m/s})(0.866)$$

$$= -52.0\ \text{kg}\cdot\text{m/s}$$

$$F_{\text{ave}} = \frac{\Delta p_x}{\Delta t} = \frac{-52.0\ \text{kg}\cdot\text{m/s}}{0.200\ \text{s}} = \boxed{-260\ \text{N}}$$

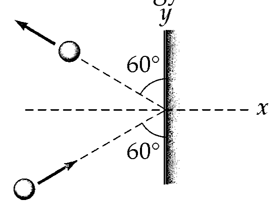


FIG. P9.9

***P9.22** For the car-truck-driver-driver system, momentum is conserved:

$$\mathbf{p}_{1i} + \mathbf{p}_{2i} = \mathbf{p}_{1f} + \mathbf{p}_{2f}: \qquad (4\,000\ \text{kg})(8\ \text{m/s})\hat{\mathbf{i}} + (800\ \text{kg})(8\ \text{m/s})(-\hat{\mathbf{i}}) = (4\,800\ \text{kg})v_f\hat{\mathbf{i}}$$

$$v_f = \frac{25\,600\ \text{kg}\cdot\text{m/s}}{4\,800\ \text{kg}} = 5.33\ \text{m/s}$$

For the driver of the truck, the impulse-momentum theorem is

$$\mathbf{F}\Delta t = \mathbf{p}_f - \mathbf{p}_i: \qquad \mathbf{F}(0.120\ \text{s}) = (80\ \text{kg})(5.33\ \text{m/s})\hat{\mathbf{i}} - (80\ \text{kg})(8\ \text{m/s})\hat{\mathbf{i}}$$

$$\mathbf{F} = \boxed{1.78\times 10^3\ \text{N}\left(-\hat{\mathbf{i}}\right)\text{ on the truck driver}}$$

For the driver of the car, $\mathbf{F}(0.120\ \text{s}) = (80\ \text{kg})(5.33\ \text{m/s})\hat{\mathbf{i}} - (80\ \text{kg})(8\ \text{m/s})(-\hat{\mathbf{i}})$

$$\mathbf{F} = \boxed{8.89\times 10^3\ \text{N}\ \hat{\mathbf{i}}\text{ on the car driver}}$$, 5 times larger.

P9.33 By conservation of momentum for the system of the two billiard balls (with all masses equal),

$$5.00\ \text{m/s} + 0 = (4.33\ \text{m/s})\cos 30.0° + v_{2fx}$$

$$v_{2fx} = 1.25\ \text{m/s}$$

$$0 = (4.33\ \text{m/s})\sin 30.0° + v_{2fy}$$

$$v_{2fy} = -2.16\ \text{m/s}$$

$$\mathbf{v}_{2f} = \boxed{2.50\ \text{m/s at } -60.0°}$$

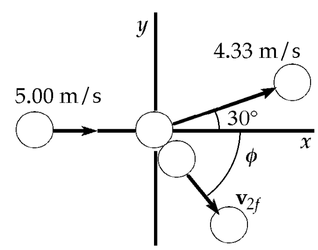


FIG. P9.33

Note that we did not need to use the fact that the collision is perfectly elastic.

P9.41 Let A_1 represent the area of the bottom row of squares, A_2 the middle square, and A_3 the top pair.

$$A = A_1 + A_2 + A_3$$
$$M = M_1 + M_2 + M_3$$
$$\frac{M_1}{A_1} = \frac{M}{A}$$

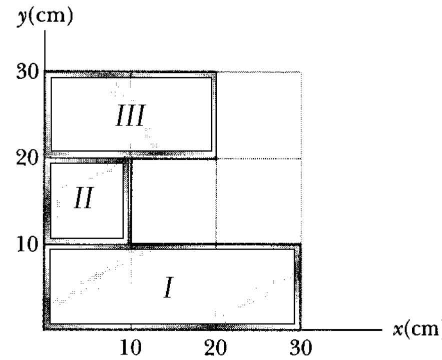


FIG. P9.41

$$A_1 = 300\text{ cm}^2,\ A_2 = 100\text{ cm}^2,\ A_3 = 200\text{ cm}^2,\ A = 600\text{ cm}^2$$

$$M_1 = M\left(\frac{A_1}{A}\right) = \frac{300\text{ cm}^2}{600\text{ cm}^2}M = \frac{M}{2}$$

$$M_2 = M\left(\frac{A_2}{A}\right) = \frac{100\text{ cm}^2}{600\text{ cm}^2}M = \frac{M}{6}$$

$$M_3 = M\left(\frac{A_3}{A}\right) = \frac{200\text{ cm}^2}{600\text{ cm}^2}M = \frac{M}{3}$$

$$x_{CM} = \frac{x_1 M_1 + x_2 M_2 + x_3 M_3}{M} = \frac{15.0\text{ cm}\left(\frac{1}{2}M\right) + 5.00\text{ cm}\left(\frac{1}{6}M\right) + 10.0\text{ cm}\left(\frac{1}{3}M\right)}{M}$$

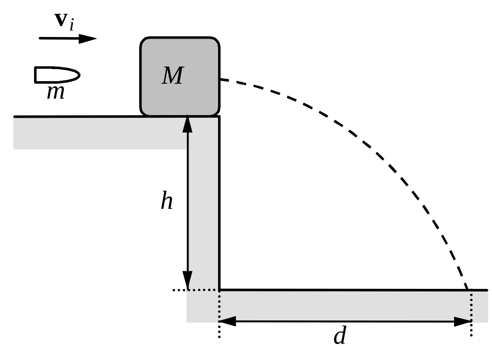
$$x_{CM} = \boxed{11.7\text{ cm}}$$

$$y_{CM} = \frac{\frac{1}{2}M(5.00\text{ cm}) + \frac{1}{6}M(15.0\text{ cm}) + \left(\frac{1}{3}M\right)(25.0\text{ cm})}{M} = 13.3\text{ cm}$$

$$y_{CM} = \boxed{13.3\text{ cm}}$$

P9.58 Using conservation of momentum from just before to just after the impact of the bullet with the block:

$$m v_i = (M + m) v_f \qquad \text{or} \qquad v_i = \left(\frac{M+m}{m}\right) v_f$$



The speed of the block and embedded bullet just after impact may be found using kinematic equations:

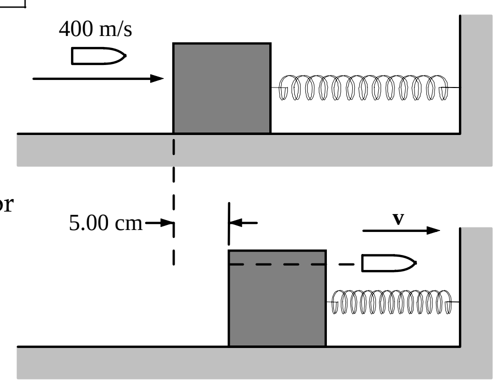
$$d = v_f t \text{ and } h = \frac{1}{2}gt^2$$

Thus, $t = \sqrt{\frac{2h}{g}}$ and $v_f = \frac{d}{t} = d\sqrt{\frac{g}{2h}} = \sqrt{\frac{gd^2}{2h}}$

Substituting into (1) from above gives $v_i = \boxed{\left(\frac{M+m}{m}\right)\sqrt{\frac{gd^2}{2h}}}$.

P9.67 (a) Find the speed when the bullet emerges from the block by using momentum conservation:

$$m v_i = M V_i + m v$$



The block moves a distance of 5.00 cm. Assume for an approximation that the block quickly reaches its maximum velocity, V_i, and the bullet kept going with a constant velocity, v. The block then compresses the spring and stops.

$$\frac{1}{2}M V_i^2 = \frac{1}{2}kx^2$$

$$V_i = \sqrt{\frac{(900\text{ N/m})(5.00\times 10^{-2}\text{ m})^2}{1.00\text{ kg}}} = 1.50\text{ m/s}$$

$$v = \frac{m v_i - M V_i}{m} = \frac{(5.00\times 10^{-3}\text{ kg})(400\text{ m/s}) - (1.00\text{ kg})(1.50\text{ m/s})}{5.00\times 10^{-3}\text{ kg}}$$

$$v = \boxed{100\text{ m/s}}$$

(b) $\Delta E = \Delta K + \Delta U = \frac{1}{2}(5.00\times 10^{-3}\text{ kg})(100\text{ m/s})^2 - \frac{1}{2}(5.00\times 10^{-3}\text{ kg})(400\text{ m/s})^2$
$+\frac{1}{2}(900\text{ N/m})(5.00\times 10^{-2}\text{ m})^2$

$\Delta E = -374\text{ J}$, or there is an energy loss of $\boxed{374\text{ J}}$.

P9.2 (a) 0; (b) $1.06\text{ kg}\cdot\text{m/s}$; upward
P9.4 (a) 6.00 m/s to the left; (b) 8.40 J
P9.6 The force is 6.44 kN
P9.8 $1.39\text{ kg}\cdot\text{m/s upward}$
P9.10 (a) $5.40\text{ N}\cdot\text{s}$ toward the net; (b) -27.0 J
P9.12 $\sim 10^3\text{ N}$ upward
P9.14 (a) and (c) see the solution; (b) small; (d) large; (e) no difference
P9.16 1.67 m/s
P9.18 (a) 2.50 m/s; (b) $3.75\times 10^4\text{ J}$
P9.20 0.556 m
P9.22 1.78 kN on the truck driver; 8.89 kN in the opposite direction on the car driver
P9.24 $v = \frac{4M}{m}\sqrt{g\ell}$
P9.26 7.94 cm
P9.28 (a) 2.88 m/s at 32.3°; (b) 783 J becomes internal energy
P9.30 $v_Y = v_i\sin\theta$; $v_O = v_i\cos\theta$
P9.32 No; his speed was 41.5 mi/h
P9.34 (a) $v = \frac{v_i}{\sqrt{2}}$; (b) 45.0° and –45.0°
P9.36 (a) $\sqrt{2}v_i$; $\sqrt{\frac{2}{3}}v_i$; (b) 35.3°
P9.38 $(0, 1.00\text{ m})$
P9.40 $4.67\times 10^6\text{ m from the Earth's center}$
P9.42 (a) see the solution; (b) $3.57\times 10^8\text{ J}$
P9.44 $0.063\,5L$
P9.46 (a) see the solution; (b) $(-2.00\text{ m}, -1.00\text{ m})$; (c) $(3.00\hat{\mathbf{i}} - 1.00\hat{\mathbf{j}})\text{ m/s}$; (d) $(15.0\hat{\mathbf{i}} - 5.00\hat{\mathbf{j}})\text{ kg}\cdot\text{m/s}$
P9.48 (a) $-0.780\hat{\mathbf{i}}\text{ m/s}$; $1.12\hat{\mathbf{i}}\text{ m/s}$; (b) $0.360\hat{\mathbf{i}}\text{ m/s}$
P9.50 (a) 787 m/s; (b) 138 m/s
P9.54 (a) $\frac{m_1\mathbf{v}_1 + m_2\mathbf{v}_2}{m_1+m_2}$; (b) $(v_1 - v_2)\sqrt{\frac{m_1 m_2}{k(m_1+m_2)}}$; (c) $\mathbf{v}_{1f} = \left(\frac{m_1-m_2}{m_1+m_2}\right)\mathbf{v}_1 + \left(\frac{2m_2}{m_1+m_2}\right)\mathbf{v}_2$; $\mathbf{v}_{2f} = \left(\frac{2m_1}{m_1+m_2}\right)\mathbf{v}_1 + \left(\frac{m_2-m_1}{m_1+m_2}\right)\mathbf{v}_2$
P9.56 291 N
P9.58 $\left(\frac{M+m}{m}\right)\sqrt{\frac{gd^2}{2h}}$
P9.60 (a) -0.667 m/s; (b) 0.952 m
P9.62 (a) 6.81 m/s; (b) 1.00 m
P9.64 (a) -3.54 m/s; (b) 1.77 m; (c) 35.4 kN; (d) No. The rails exert a vertical force to change the momentum
P9.66 0.312 N to the right
P9.68 0.179 m/s
P9.70 (a) 3.7 km/s; (b) 153 km
P9.72 (a) 3.75 N to the right; (b) 3.75 N to the right; (c) 3.75 N; (d) 2.81 J; (e) 1.41 J;
(f) Friction between sand and belt converts half of the input work into extra internal energy.